WE CLAIM:

1. An apparatus for direct conversion of hydrocarbons, comprising:

a dielectric barrier discharge plasma cell comprising an outer electrode and an inner electrode with a dielectric material and a passageway therebetween;

a solid oxide electrochemical cell in fluid communication with the discharge plasma cell, the electrochemical cell comprising:

a mixed-conducting solid oxide electrolyte membrane tube;

a porous anode on an exterior surface of the electrolyte membrane tube;

a porous cathode on an interior surface of the electrolyte membrane tube opposite from the porous anode; and

a gas inlet tube for feeding oxygen containing gas to the porous cathode;

an inlet for feeding hydrocarbons to the passageway of the discharge plasma cell; and

an outlet for discharging reaction products from the electrochemical cell.

2. The apparatus of claim 1, wherein the inner electrode comprises a catalyst material.

3. The apparatus of claim 1, wherein the inner electrode is constructed of a catalyst material.

4. The apparatus of claim 1, wherein the inner electrode has a catalyst material coating thereon.

5. The apparatus of claim 2, wherein the catalyst material comprises a hydrocracking catalyst or a hydrotreating catalyst.

6. The apparatus of claim 1, wherein the inner electrode comprises a non-catalytic base metal, and a bimetal catalyst overlying the base metal.

7. The apparatus of claim 1, wherein the inner electrode comprises a non-catalytic base metal, and two different bimetal catalysts overlying the base metal for successive catalytic hydrocracking and catalytic hydrotreating of feed hydrocarbons.

8. The apparatus of claim 1, wherein the inner electrode comprises a first catalytic base metal, and a second catalytic metal overlying the base metal.

9. The apparatus of claim 1, wherein the inner electrode comprises a catalytic base metal, and two different catalytic metals overlying the base metal for successive catalytic hydrocracking and catalytic hydrotreating of feed hydrocarbons.

10. The apparatus of claim 1, wherein the inner electrode comprises one or more materials selected from the group consisting of cobalt, nickel, platinum, rhenium, molybdenum, tungsten, palladium, and combinations thereof.

11. The apparatus of claim 1, wherein the mixed-conducting solid oxide electrolyte membrane tube comprises CeO_2 doped with CaO.

12. The apparatus of claim 1, wherein the porous anode comprises a catalyst material.

13. An apparatus for direct conversion of hydrocarbons, comprising:

a dielectric barrier discharge plasma cell comprising an outer electrode and an inner electrode with a dielectric material and a passageway therebetween;

a solid oxide electrochemical cell in fluid communication with the discharge plasma cell, the electrochemical cell comprising:

a mixed-conducting solid oxide electrolyte membrane tube;

a porous anode on an exterior surface of the electrolyte membrane tube;

a porous cathode on an interior surface of the electrolyte membrane tube opposite from the porous anode; and

a gas inlet tube for feeding oxygen containing gas to the porous cathode;

an inlet for feeding hydrocarbons to the passageway of the discharge plasma cell;

an outlet for discharging reaction products from the electrochemical cell; and

a packed bed catalyst in the discharge plasma cell and the electrochemical cell.

14. The apparatus of claim 13, wherein the packed bed catalyst comprises a material selected from the group consisting of a hydrocracking catalyst, a hydrogenating catalyst, and combinations thereof.

15. The apparatus of claim 13, wherein the packed bed catalyst comprises one or more materials selected from the group consisting of cobalt, nickel, platinum, rhenium, molybdenum, tungsten, palladium, and combinations thereof.

16. The apparatus of claim 13, wherein the inner electrode comprises a catalyst material.

17. An apparatus for direct conversion of hydrocarbons, comprising:

a dielectric barrier discharge plasma cell comprising an outer electrode and an inner electrode with a dielectric material and a passageway therebetween;

a solid oxide electrochemical cell in fluid communication with the discharge plasma cell, the electrochemical cell comprising:

a mixed-conducting solid oxide electrolyte membrane tube;

a porous anode on an exterior surface of the electrolyte membrane tube;

a porous cathode on an interior surface of the electrolyte membrane tube opposite from the porous anode; and

a gas inlet tube for feeding oxygen containing gas to the porous cathode;

an inlet for feeding hydrocarbons to the passageway of the discharge plasma cell;

an outlet for discharging reaction products from the electrochemical cell; and

a light source for directing ultraviolet light into the discharge plasma cell and the electrochemical cell.

18. The apparatus of claim 17, wherein the light source is positioned within the inner electrode.

19. The apparatus of claim 17, wherein the light source is positioned external the inner electrode.

20. The apparatus of claim 18, wherein the inner electrode is constructed of a metallic screen shell.

21. The apparatus of claim 20, wherein the inner electrode is supported by a transparent housing structure.

22. The apparatus of claim 18, wherein the light source is contained within a transparent housing structure.

23. The apparatus of claim 19, wherein the light source is external a transparent housing structure.

24. The apparatus of claim 17, further comprising a packed bed catalyst in the discharge plasma cell and the electrochemical cell.

25. The apparatus of claim 24, wherein the packed bed catalyst comprises a material selected from the group consisting of a hydrocracking catalyst, a hydrogenating catalyst, and combinations thereof.

26. A method for direct conversion of hydrocarbons, the method comprising:

directing a hydrocarbon feed through a dielectric barrier discharge plasma to produce reactive hydrocarbon species;

passing an oxygen containing gas through a mixed-conducting solid oxide electrolyte membrane tube, having a porous anode on an exterior surface thereof and a porous cathode on an interior surface opposite from the porous anode, to thereby produce reactive oxygen-containing species;

reacting the hydrocarbon species with the oxygen-containing species to produce liquid products comprising fuel-type hydrocarbons and oxygenated hydrocarbons.

27. The method of claim 26, wherein the hydrocarbon species is reacted with the oxygen-containing species in the presence of a catalyst material.

28. The method of claim 26, wherein the fuel-type hydrocarbons comprise gasoline or diesel.

29. A method for direct conversion of hydrocarbons, the method comprising:

directing a hydrocarbon feed through a dielectric barrier discharge plasma to produce reactive hydrocarbon species;

passing an oxygen containing gas through a mixed-conducting solid oxide electrolyte membrane tube, having a porous anode on an exterior surface thereof and a porous cathode on an interior surface opposite from the porous anode, to thereby produce reactive oxygen-containing species;

reacting the hydrocarbon species with the oxygen-containing species in the presence of a packed bed catalyst to produce liquid products comprising fuel-type hydrocarbons and oxygenated hydrocarbons.

30. The method of claim 29, wherein the fuel-type hydrocarbons comprise gasoline or diesel.

31. A method for direct conversion of hydrocarbons, the method comprising:

directing a hydrocarbon feed through a dielectric barrier discharge plasma to produce reactive hydrocarbon species;

passing an oxygen containing gas through a mixed-conducting solid oxide electrolyte membrane tube, having a porous anode on an exterior surface thereof and a porous cathode on an interior surface opposite from the porous anode, to thereby produce reactive oxygen-containing species;

reacting the hydrocarbon species with the oxygen-containing species in the presence of ultraviolet light to produce liquid products comprising fuel-type hydrocarbons and oxygenated hydrocarbons.

32. The method of claim 31, wherein the hydrocarbon species is reacted with the oxygen-containing species in the presence of a packed bed catalyst.

33. The method of claim 31, wherein the fuel-type hydrocarbons comprise gasoline or diesel.